Age Determination of T Tauri Stars by High-Resolution Near-Infrared Spectroscopy

Yuhei Takagi(takagi@stu.kobe-u.ac.jp), Yoichi Itoh, Yumiko Oasa
Kobe University

Abstract

Since pre-main sequence stars contract in the evolutional process, age can be estimated from surface gravity. We present a new method to determine the age of T Tauri stars by deriving its surface gravity with near-infrared high-resolution spectroscopy. We measured the equivalent width ratio of nearby absorption lines to eliminate the effect of veiling such as "filling up". We obtained the spectrum of stars which its effective temperature are subequal to establish a indicator of surface gravity, and found that the ratio of Sc and Na in K-band is suitable for deriving the gravity. The age of T Tauri stars can be determined with a precision of the factor of 1.5 using Sc/Na.

Introduction

Importance of T Tauri stars' age

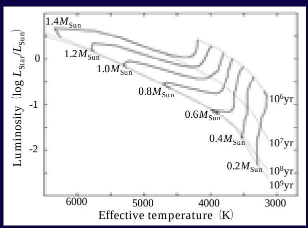
There are many unknown mechanisms in the evolutionary process of young stars such as…

- evolution of protostars, protoplanets, protoplanetary disks, and outflow
- rotational speed reduction of photosphere etc.

A precise age determination is essential to solve these problems.

General age determination method

Absolute luminosity and effective temperature of YSO changes during its evolution;



⇒ Age can be determined by deriving the SED of YSO from photometry.

Fig 1. The HR diagram with evolutionary tracks of 0.2~1.4Msun stars. The solid lines are the evolution tracks, and the dashed lines are isochrones. (Baraffe et al 1998).

■ The Problem of the general method

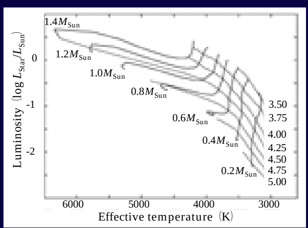
I. Distance indefiniteness
II. Extinction caused by circumstellar material
III. Veiling (The continuum excess arises from the heated disk and accretion shock)

⇒ The derived luminosity are inaccurate (leads to incorrect age)

The New Method

Determining the Age from surface gravity

YSO contracts in early evolutional process ⇒ Surface gravity will increase



Age can be derived by estimating the surface gravity (without using luminosity)

Fig 2. The HR diagram with evolutionary tracks of 0.2~1.4Msun stars (solid) and constant-gravity lines (dashed, values are log g [cm/s²]).

How to estimate the Surface gravity of YSO with spectroscopy

The equivalent width (EW) of absorption lines depend on…

1. Metal abundance 2. Effective temperature 3. Surface gravity

＜Surface gravity's dependence on EW＞

A. Wing; gets larger when the gravity increases.
(High S/N & High-resolution observation is needed)

B. The dependence of continuous absorption coefficient

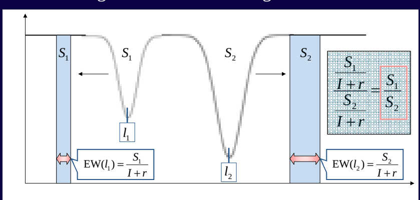
$$\frac{\kappa_\lambda}{\kappa} = \frac{T^{\frac{5}{2}}}{P_e}\exp\left(-\frac{\chi+0.75}{kT}\right) \qquad P_e \sim g^{\frac{1}{3}}$$

κ_λ: Line absorption coefficient
κ: continuous absorption coefficient g: surface gravity
P_e: electron pressure T: effective temperature
χ: excitation potential k: Boltzmann constant

Line strength is proportional to -1/3 of the surface gravity

＜Calculation of EW ratio＞

(1) Canceling the EW difference arises of metal abundance
(2) Removing the effect of Veiling



Effect of Veiling can be removed by calculating the EW ratio of *nearby* absorption lines

Ratio created by absorptions which are not close each other (ex. Na@2.2μm and CO@2.3μm (Doppmann et al. 2002)), veiling correction is needed using model spectra. However, the correct veiling value is difficult to estimate.

＜Absorption lines selection＞

(I) Strongest line in near-infrared (near-infrared is desirable to observe YSO)
⇒ Na [2.2062μm] (not sensitive to surface gravity since it is reached to limiting depth)

(II) Strong line (easy to observe, not reached to limiting depth) which is close to Na
⇒ Sc [2.2057μm]

We establish a new surface gravity indicator using the EW ratio of Sc and Na (Sc/Na)

To derive the relation between Sc/Na and surface gravity, we obtained the spectrum of stars which have subequal effective temperature.

Data

We obtained the spectrum of dwarf (gravity larger than YSO) and giants (gravity smaller than YSO) to derive the relation between Sc/Na and the surface gravity.

Observation

Instruments	Subaru Telescope IRCS		
Date	16~18, Sep. 2008	Filter	K-band
Resolution	~20000	S/N	100~150
Targets	Dwarf, YSO, and giant which its surface gravity is known*. The spectral types are late-K to early-M.		

Archival data

＜Kitt Peak observatory＞

Instruments	Mayall 4m Telescope	Filter	K-band
Resolution	45000~91000		

＜Gemini observatory＞

Instruments	Gemini South Phoenix	Filter	K-band
Resolution	40000		

We obtained the spectrum of 3 dwarfs, 1 giant and 1 supergiant which its surface gravity is known*. The spectral types are late-K to early-M.

＊Surface gravity
Calculated by the expression below. (M and T are estimated from Sp. type, and L is from the distance and visual magnitude.)

$$\log\frac{g}{g_{Sun}} = \log\frac{M}{M_{Sun}} + 4\log\frac{T}{T_{Sun}} - \log\frac{L}{L_{Sun}}$$

g: surface gravity M: mass
T: effective temperature L: luminosity

Result

Spectrum

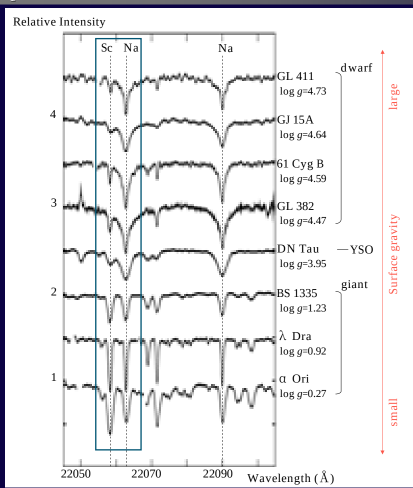


Fig.3 The spectrum of 8 objects

Na is not sensitive to the surface gravity since it is reached to limiting depth.

Sc is sensitive to the surface gravity. Its absorption strength gets larger when the surface gravity decreases.

Precision of Sc/Na

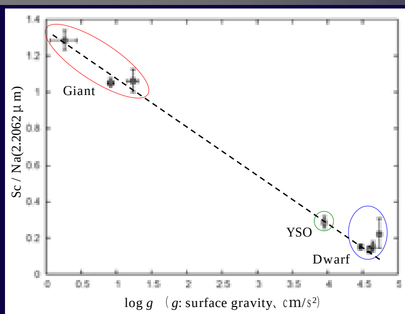


Fig. 4 The relation between Sc/Na and surface gravity

Sc/Na decreases when the surface gravity increases.

Surface gravity can be derived by calculating Sc/Na

We estimated the surface gravity determination accuracy of Sc/Na by approximating the plots by linear.

⇒ log g can be determined with a precision of ±0.12

Then, by comparing this result with the evolution model of Baraffe et al. (1998)…

The age of YSO can be determined with a accuracy of the factor of 1.5.

Conclusion

○ We discussed the new method to determine the age with near-infrared high-resolution spectroscopy.

○ The EW ratio of Sc and Na (Sc/Na) in the K-band is a good indicator of surface gravity. The age of YSO can be determined correctly from the surface gravity, which is able to determine from Sc/Na.

○ For future works, we will obtain more spectrum to derive the correct relation between log g and Sc/Na. Then, we will discuss about the timescale of YSO evolution.